3 Two Decades of Interactive Art: Digital Technologies and Human Experience

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As I write this in 2011, it is sobering to reflect on the fact that after a couple of decades of explosive development in new media art—or "digital multimedia" as it used to be called—in screen-based as well as "embodied" and gesture-based interaction, there seems not to have been much advance in the aesthetics of interaction. At the same time, interaction schemes and dynamics once only known in obscure corners of the world of media art research/creation have found their way into commodities from 3-D TV and game devices (Wii, Kinect) to smartphones (iPhone, Android). While increasingly sophisticated theoretical analyses (from Lev Manovich to Wendy Hui Kyong Chun to Mark Hansen, and more recently Nathaniel Stern among others) have brought diverse perspectives to bear, I am troubled by the fact that we appear to have advanced little in our ability to qualitatively discuss the characteristics of aesthetically rich interaction and interactivity—not to mention the complexities of designing interaction as artistic practice—in ways that can function as a guide to production as well as a theoretical discourse. This essay is an attempt at such a conversation.[1]

Historical Gloss—the Confluence of Two Great Rivers

I identify a two-decade period—roughly speaking from 1985 to 2005—as the pioneering experimental period of (computer-based) interactive art. At the beginning of the period the graphical user interface was a novelty, the Internet barely existed, the web was a decade away, and interactivity was an intriguing concept. The production of acceptably high-resolution illusionistic digital pictures (still frames) was an active research area, and a megabyte of RAM was something luxurious. This period neatly brackets the emergence of most of the major technological milestones, which now undergird digital culture and ubiquitous computing: WYSIWYG, digital multimedia, hypermedia, virtual reality, the Internet, the World Wide Web, digital 3-D animation, real-time graphics, digital video, mobile telephony, GPS, Bluetooth, and other mobile

and wireless communication systems. It was a period of rapid technological change, euphoria, and hype. Crucial to the understanding of work in this period is the blindingly rapid development of the technological context.

Over these (roughly) two decades of practice, interactive aesthetic strategies were developed and adapted to the constraints of digital technologies—themselves under rapid development through this period—and substantial technical R+D as well as aesthetic research was undertaken by artists. In fact, technical and aesthetic developments were inseparable. This was a defining characteristic of the work of that period. Less obviously, digital and interactive practices were (only) slowly assimilated into the corpus of fine-arts practices and cross-fertilized with more traditional aesthetic approaches.

Within the context of experimental arts practices, a space opened up for the development of interaction that was less overwhelmed by the instrumental and individualistic modalities characteristic of the computer industry. This movement was infused with the spirit of post-1960s experimental art practices—the "art and technology" movement, performance, video installation, and expanded cinema. At the same time it was informed by generative systems and artificial life, and discourses of emergent complexity and self-organization that link back to cybernetic conceptions of responsive systems, as well as by the dominant, computationalist-cognitivist discourses around programmability and the hardware/software dual. This in turn led to a great flowering of confused rhetoric around the concept of "virtuality"—a concept that arose chimerically at the intersections of a variety of utopic and dystopic fantasies—and slunk back into the gloom just as quickly.[2]

The domain of interactive art over this period was a space of free invention, an anarchic research realm, less application-driven and relatively free of market directives: all kinds of experimental interaction modalities were realized by artists—many deploying custom technologies in code and/or hardware. The necessity to develop tools was double-edged—on the one hand it permitted an organic development process, in which the specifications of the technologies arose from theoretico-aesthetic requirements (and sometimes, vice versa). On the other hand, the task of running an engineering R+D lab with limited technical skills and usually very limited budgets was stressful and fatiguing. This required highly inventive logistical strategizing and the development of a *digital bricolage* practice, which was often sneered at by engineers and computer scientists as a dilettantist kludge. Without recognizing these special conditions, it is not possible to grasp the significance of the work that arose in that period.

Because of the sensitivity of artists to persuasive sensorial immediacy and embodied engagement, interactive art practices pioneered research into various dimensions of interaction long before they were recognized as research agendas in academic and

corporate contexts. Many of the ideas that now inform burgeoning fields—such as tangible interfaces, affective and ubiquitous computing—appear in digital artworks of the 1990s and earlier. In some cases, such work remained unknown outside a relatively closed tech-art community, and was independently re-created in other contexts. In other cases, the transfer was more explicit and sometimes resembled plundering. Over the last decade, much of the product of interactive art research has found its way into commercial digital commodities, but in this shift in socioeconomic context, a process of erasure of historico-aesthetic significance has occurred. It is an odd feeling to see, in a few short years, systems that were perceived as having rich aesthetico-theoretical presence trivialized as mass-produced commodities deployed in a paradigm of vacuous "entertainment."

Echoing the fundamental hardware/software binary of computer science, mainstream digital discourses were undergirded by a commitment, stated or unstated, to a rhetorical opposition of materiality and the "digital," especially in the early years. This led to a deep and polarizing discursive tension with the embodied and holistic perspectives of traditional fields of practice, rendering one camp "Luddite" and the other "technofetishist." The centrality of the negotiation of materiality, embodiment, and sensorial experience within digital arts practices is, in my opinion, fundamental to understanding the history of interactive art, and provides a purchase with which to understand transitions to ubiquity.[3]

The advent of cheap, Internet-marketed microcontrollers, sensors, programming environments, and the like has made the practice far more amenable to technological novices. It also has created a new set of aesthetico-technological challenges in the sense that these commodity widgets are designed to fit a narrow consumer need and thus have all kinds of assumptions built into them (image "improving" algorithms and digital video formats, for example) that are often difficult to isolate, let alone work around.

Interactive Art before the PC

While the notion of a performative and processual aesthetics of interaction has been bandied about for twenty years or so, there has been little in the way of development in the formal qualities of interaction that were not already pioneered in the 1970s. *The Senster* by Edward Ihnatowicz (1970) neatly framed agendas of reactive robotics, biomimetic robotics, and social robotics, in a robust and persuasive public demonstration twenty-five to thirty years ahead of the institutional curve.[4] Myron Krueger pioneered machine vision-based embodied screenal interaction in several works, the most well

(a)

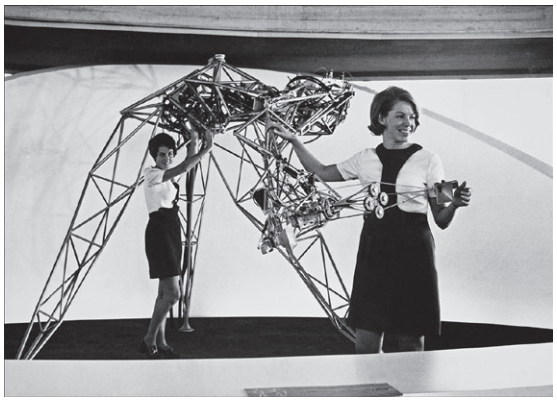

Figure 3.1a
Edward Ihnatowicz, *The Senster,* 1970–74. View of the robotic sculpture commissioned by Philips in 1970 for its permanent showplace in Eindhoven, the Evolon. Courtesy of Richard Ihnatowicz.

(b)

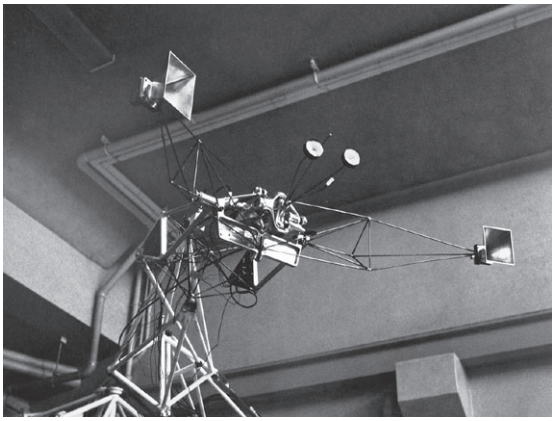

Figure 3.1b
Edward Ihnatowicz, *The Senster,* 1970–74, detail. Courtesy of Richard Ihnatowicz.

known being *Videoplace* (1975). There is little in the interaction dynamics of the Wii or the Kinect that was not prototyped in the several iterations of *Videoplace* forty years before.[5]

In terms of autonomous behavioral repertoire, Grey Walter's "turtles" of the late 1940s set a standard for machine behavior seldom exceeded since. These devices, built with minimal (and by today's standards, rudimentary) technology, displayed behaviors seen today in artworks and robotic toys. The turtles were made not as artworks but

(c)

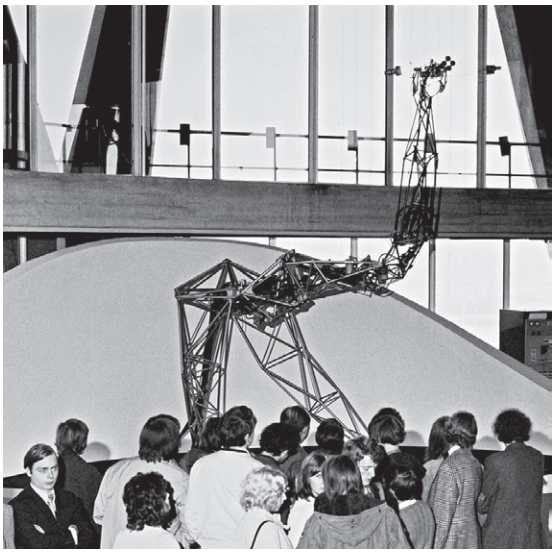

Figure 3.1c
Edward Ihnatowicz, *The Senster,* 1970–74. View of the robotic sculpture commissioned by Philips in 1970 for its permanent showplace in Eindhoven, the Evolon. Courtesy of Richard Ihnatowicz.

as cybernetic experiments into electronic "brains." It is important to recognize that, consistent with the cybernetic context he worked in, the conception of "intelligence," which Walter sought to simulate, was thoroughly *situated*.[6] The complexity of the creative agency of Gordon Pask's *Musicolor*, first presented in 1953, is likewise seldom attained.[7] The turtles and *Musicolor* were entirely analog, and *Senster* had the digital processing power, roughly, of an Arduino.[8]

These works provide a pre-digital or at least preconsumer-digital reference point for interactive art. It is important to recognize that they arose within the discursive context of cybernetics—as opposed to the cognitivist regime of late-twentieth-century computing—and prior to the overwhelming presence of the digital commodity industry. In this light, we must consider the last quarter century, not simply as a period of adaptation and invention in a new technological context, but as a period of increasingly successful attempts at rehabilitation from the disembodying narratives of the cognitivist and the "digital."

The rapid advance in bells and whistles permits interfacial cosmetic niceties undreamable twenty years ago, and the technofetishism of higher resolutions and faster bit-rates serves the needs of an industry that depends on obsolescence (as perceived or as inbuilt

Figure 3.2
Time-lapse (and multiple exposure) photo of American neurophysiologist and roboticist Dr. William Grey Walter (1910–1977) smoking a cigarette while his robots Elmer (left) and Elsie leave light trails as they move around a chair and table, April 1950. Photo Larry Burrows / Time & Life Pictures / Getty Images.

material breakdown) to remain profitable, often deploying novelty to obscure a void of significant advancement.[9] Regrettably, Moore's law does not operate in the aesthetico-theoretical realm.[10]

Toward a Performative Aesthetics

Much early interactive artwork arose in the context of the plastic and visual arts, and as such, artists experienced a theoretical void. Whatever the theoretical tools available to address matters of form, color, expression, and embodied sensorial engagement, those traditions had little to say about ongoing dynamic temporal engagement because *traditional art objects do not behave*. Questions like, "How does the act of interaction *mean*?"

and "How are such valences to be manipulated for enriched affective practice?" are fundamental questions in the aesthetics of interactive art, but find no answers in the aesthetics of the plastic arts.[11]

Long ago R. Buckminster Fuller asserted, "I seem to be a verb."[12] This sentiment informed much of the emerging art practices of the 1960s, which emphasized process—performance or site-specific art of various kinds, for instance. In more recent discourse, each of the following terms—*dynamical*, *processual*, *procedural*, *performative*, *situated*, *enactive*, and *relational*—in its own theoretical context captures the evanescent process of contextualized doing. This represents a groundswell in the theorization of cultural practices sympathetic with phenomenological approaches, and by extension with emerging postcognitivist cognitive science. I see this trend here as a critical paradigm shift, which has major implications for the theory and practice of interactive art.

After Nature/Nurture

We seem incorrigibly drawn to dualizing, and the nature/nurture, biology/culture dual is as ubiquitous and invidious as the mind/body dual.[13] Interactive art, being a radically interdisciplinary realm, is also one in which scientific and humanistic narratives collide. (The *science wars* have been a constant backdrop to work and theorization in the field.) Yet to the extent that interaction is an embodied process, neat separations of biology and culture disappear. My position here is evolutionary and materialist: interaction makes sense to the extent that it is consistent with, or analogous to, the learned effects of action in the "real world." Our ability to predict, and find predictable, behaviors of digital systems is rooted in evolutionary adaptation to embodied experience in the world. We are, first and foremost, embodied beings whose sensorimotor acuities have formed around interactions with humans, other living and nonliving entities, materiality and gravity. We understand digital environments on the basis of extrapolations upon such bodily, experience-based prediction. This is easy to understand in mimetic environments such as Second Life, but is equally present in more a basic mouse-screen level of interaction. Our most common interactive modalities subscribe to or enlist associations that are deeply sensorimotoric in nature, and perhaps draw upon DNA hardcoding.

Aside from the trivially Pavlovian modality (press the button and get the reward/food pellet), what are the key interactive modalities in artworks? In installation and robotic work, many examples exploit a zoomorphic *puppy paradigm* of approach and withdrawal, trust and fear. This is always beguiling—for a while. Is the charm of this

modality somehow "natural" to us as humans, perhaps hardcoded into our DNA as parenting animals? This question opens a field of inquiry at the intersection of neuroethology and interactive aesthetics. Whatever the case, the next question is how to move aesthetic development of the field beyond this biological or cultural "ground zero."

It is a seldom-noted corollary to the panegyric around "the virtual" that many interactive art projects focus on the dynamics of embodied interaction;[14] this central aspect of human being-in-the-world was poorly (and conspicuously) addressed in conventional sit-at-a-desk computer systems. In the contemporary context, this situation has changed in two ways. Interface technologies are far more diverse, complex, and subtle. Not long ago, microphones and cameras were exotic add-ons to computers. The accelerometers now ubiquitously embedded in handheld devices have been deployed (in miniature) for all kinds of movement-based apps.[15] And yet, first-generation interactive modalities involving pointers and keyboards hang on skeuomorphically, emulating their physical counterparts in digital forms. Of all the things I do in my life, only some of them map well onto sitting at a desk in front of a glowing surface, poking at buttons, and this situation is not improved one iota when the context is miniaturized so the buttons are smaller than my fingers and I have to put my reading glasses on to look at the screen. For all the expansion of connectivity we have not progressed very far in interactive modalities.

More subtly, members of the first generation to have lived with digital devices during infancy are now adults. This generation is acculturated to, for instance, multimodal on-screen interfaces. These people's neurology must have, to some extent, formed and developed around such systems. That is, the metaphors and behaviors of digital systems, like any aspect of language and culture inculcated in infancy, have generated isomorphic neurological structures—digital metaphors instantiated at the level of cellular biology.[16]

Who or What Is Interacting? Analysis of Interactive Systems

Conversations regarding the aesthetics of interaction have been characterized by a not-entirely clearly elucidated swing between preoccupation with subject experience and an emphasis on the behavior of the artifact/system. The question "Is it interactive?" can have wildly different answers depending on this point of view. Assertions such as "viewing a photograph is 'interactive'" are clearly nonsensical if one is looking from the perspective of the artifact/system, and they are destructive to the goal of building a richer critical discourse about interactive systems. The photograph does not change

in any way due to changes in its environment. A human viewer might have varying experiences due to personal associations, varying proximity, or lighting conditions, but there is no *interaction* in the sense of an ongoing sequence of mutually determining actions between two systems possessing agency, or as interacting components in the larger user/machine system.[17]

There is undoubted value in probing the nature of the interactive aesthetic experience on the part of the subject.[18] The study of the design of the system as an armature upon which the experience occurs is a necessary complement. Such a design-centric approach engages issues such as designer authoriality and the position of the system as a *literature*,[19] or as quasi-organism, in autopoietic or enactive sensorimotor loops with user(s).[20] From the perspective of machine design, the fundamental requirement of an interactive system is that it correlates data gathered about its environment (usually a user's behavior) with output in a meaningful way. The system must present effects that are perceived by users as being related to their actions. Without this there is no perception of interactivity.

But this does not mean that only literal or instrumental modalities can be meaningful. Temporal immediacy permits aesthetic deployment of sleight of hand. If I knock a glass and it falls to the floor splintering, I assume a physical and temporal causality. Assumption of causality based on temporal order can be "designed-in" and exploited in interaction design. As in film montage, diverse elements and events can be connected by an associative or inferential temporal sequencing. The aesthetic manipulation of temporal process is central to the poetics of interaction design.

Temporality and Poetry in Interaction

The very success of commercial commodity interactive digital multimedia (and its rhetorics) has impeded aesthetic progress in the field, because these media have created some confusion between interactivity for instrumental purposes and interactivity for cultural purposes. The interactivity of conventional software tools (say a word processor) should ideally be "transparent" and instrumental. What is meant by "transparent" and "intuitive" in such discourse is that the behavior of the system is consistent with previously learned bodily realities.[21] In Heideggerian terms, instrumental software should be "ready-to-hand." To the extent that it is noticeable, it is bad. This, one might argue, is exactly the opposite of what aesthetic interaction ought to be—it should not be predictably instrumental, but should generate behavior which exists in the liminal territory between perceived predictability and perceived randomness, a zone of surprise, of poetry.

To the extent that every digital interactive event is analogical, interaction is always poetical, and the construction of instrumental systems involves reduction of the poetry quotient. And in many cases, the focus of the artist has been precisely to probe the qualities of this analogizing. This is most often obvious in augmented and mixed reality projects where the behaviors in the digitally constructed environment maintain certain consistencies but invert, erase, or otherwise distort other correspondences. User representation may be abstracted but temporal correspondences make it abundantly clear what aspects of the image correspond to what body part or gesture.

The persuasiveness of interaction is intimately temporal. Such correspondences leverage deeply embodied sensorimotor understandings—specifically the affiliation of proprioceptive and visual feedback. The real-time computer-vision representation of the user almost instantly obtains a prosthetic functionality, testifying to a remarkable speed of neurological mapping across modalities.[22] Indeed, without such capability we would be unable to drive a car or use a screwdriver. *Real-timeness* is not easily subtracted from the screwdriver, but it was a technical challenge for vision-based work, and as such the symptom acquired a name—latency. The very existence of latency led to exploration of the sensorimotor requirements of the perception of real-timeness. Sensory modalities have varying conceptions of "now." "Now" is shorter and sooner in hearing than in vision.

The question of interaction has cognitive and phenomenological dimensions that have ramifications for the development of adequate aesthetic theory for the practice. In interactive work that arises from a tradition of plastic or visual arts, conventional aesthetic language imposes an axiomatic subject-object distinction upon the artwork/interactor system. This has the effect of obscuring the very (relational) nature of the experience. A distinction must be drawn between two paradigmatic modalities of interaction deployed in cultural practices, which we might identify as "instrumental" and "enactive." The instrumental mode, typified by HTML links and its hypertextual predecessors (all the way back to HyperCard), regards the enaction of a link as simply a way to get from A to B—a connection, which (ideally) is instantaneous and is not marked as an event in itself. A and B are the objects of concern—they are objects, and nothing else is of concern. Effects such as fades or wipes, borrowed from video and cinematic language, tend to be distractions or at best to signify a change of temporal or spatial context, register, and so forth.

Fuller's earlier quoted cybernetically inspired locution, "I seem to be a verb," was informed by the doubly continuous nature of the analog electronic signal: as temporally continuous and amenable to infinite resolution. Both of these conditions are artificially curtailed by the discreet nature of digital data—a fact that, via rhetorics

of object-oriented programming and the like, may have informed the object-centric nature of instrumental interaction. This erasure of temporal process is typical of the object-centric ways we tend to explain experience. The cinematic "frame" and its metaphoric extension into analog and digital video realms creates the sense that time is composed of a sequence of stoppages.

The lesson of performativity is that the doing of the action by the subject in the context of the work is what constitutes the experience of the work. It is less the destination, or chain of destinations, and more the temporal process that constitutes the experience. To call it "content" would be again to slip into objectivizing language. In what follows I will deploy the concept of "enactive cognition" of Francisco Varela, Evan Thompson, and Eleanor Rosch as it captures the ongoing "structurally coupled" nature of experience as "laying down a path in walking."[23] It is precisely this (performative) aspect of the aesthetics of interaction that demands theoretical elaboration.[24]

The Implicit, Enactive, Performative Body

Discussions of interactive art have a dialectical quality. On the one hand, an arts/humanistic approach all but ignores the nature of the technological vehicle. On the other hand, technocentric approaches tend toward instrumentalization of the user and the trivialization of precisely the phenomenon that is in need of explication. (Ultimately some critical purchase must be made upon the behavior of the complete [user/machine] system.) This difference might be conceptualized in ontological terms—is meaning gathered as a result of the extraction of representational tokens, or is it enactively constructed in doing? In his insightful discussion of interactive art, Nathaniel Stern marshals insights from performance studies to formulate a conception of the "implicit body," a Deleuzian "body in motion."[25] Central to his analysis is an awareness of the dynamical condition of interaction—a perspective that is in cognitive terms *enactive*. As an interdisciplinary intervention, projects like Stern's have the salutary effect of balancing the weight of a technocentric and instrumental approach which often has the effect of rendering the user as a "robot" or a Pavlovian subject capable of a limited range of behaviors elicited by specific stimuli. Crucial to Stern's analysis is an understanding of temporally and spatially ongoing embodiment as the locus within which meaning is created. Such a position is in Philip Agre's terms *deictic*, and in Andrew Pickering's *performative*.[26] This confluence of Varela and Gilles Deleuze, Agre, and Pickering[27] points to a new ontological perspective from which interaction, and the interactor, can be usefully reformulated, and from which advances in interaction design practice and theorization might be made.

We may say interactive artworks provide a context in which engagement with the work constructs a condition that requires further action in order to be resolved—in which artifacts and effects are arrayed spatially and temporally so as to encourage the formulation of novel ideas. The temporality of the process is unavoidable, and its design constitutes a kind of synthetic enactionism. The arrangement of such conditions in a way that optimally stimulates such processes (bearing in mind questions of demographics and cultures) is a cognitive dimension of interaction design for aesthetic purposes.

The Role of Epistemic or Performative Action in Interaction

Interaction dynamics are (clearly) not the only dimension of meaning construction in interactive art. We should distinguish between interface and interaction modalities that are deployed as a mechanism for exploring "content," and modalities which themselves contribute to the accumulated meaning or experience of the work. As discussed above, in some interactive work, interactive modalities are taken as transparent and given: the dynamics of interaction were conceived as a means to an end that was primarily found in the "content" of the work (as if interaction dynamics were not always part of the "performative" content). This is a rather conservative notion of interaction. In other cases, the dynamics of interaction play a key role in the overall construction of meaning.[28]

The recognition that interaction is both embodied and quintessentially performative provides a position from which to build out an aesthetic theory. Pickering's formulation that the representational and performative idioms are distinct, and perhaps incommensurable, is relevant.[29] Originally applied to questions of scientific knowledge and practice, this binary is ripe for application to art practices, for conventional plastic arts artifacts are representational artifacts par excellence. Interactive cultural practices, while deploying representational components, prescribe a performative ontology—some more than others. Again—to the extent that the mechanisms of interaction are naturalized, automatic, "intuitive"—they do not play a significant part in the epistemological circuits of the work. When I have to bend *this way*, climb *that* ladder, or stand with my feet in cold water: the doing of the work, the embodied and performative dimensions are, and must be, designed as (often major) components in the overall meaning of the work.

The distributed cognition research of Edwin Hutchins and David Kirsh offer a way of asking how interactions mean. Both researchers are concerned with how bodily action plays a role in cognitive processes involving manipulation of artifacts and exploitation

of images.[30] Building such meaning has several aspects. Making a user complicit in the construction of an unfolding experience is a powerful technique for establishing engagement and commitment. If seeing a video in which a person is pushed off a balcony is disturbing, pushing them yourself—or being put in the position of choosing to—is an order of magnitude. (Unless of course such action is routinely trivialized, as in first-person shooter games.) Aside from ethical issues, basic sensorimotor realities anchor interaction in a way that dissociated contemplative vision never can. As embodied beings, we conduct our path through the world in the form of sensorimotor circuits, which have no beginning or end. Contrary to received wisdom, humans rarely perceive-then-act, but understand the world in a synaesthesic and proprioceptive fusion of sensing and action, often acting in order to perceive. An aesthetic theory of interaction, then, must include a choreographic understanding of perception and action.

It is not just doing, or not just the awareness of doing, but the cognitive dimensions of doing that are important dimensions of interaction design. Kirsh and Paul Maglio demonstrated a phenomenon they call "epistemic action,"[31] which describes the gathering of knowledge through action in the world. That is, certain kinds of things can only be thought, or can be thought faster, more efficiently, or more richly, by the manipulation of objects in the material world. Think of moving the Scrabble letters about to suggest words. An array of utensils and ingredients on a kitchen bench might suggest action, the shape of the knife facilitates certain kinds of actions (and not others), but does the arrangement and design of implements support thinking? Kirsh and Maglio's Tetris research addresses time-constrained problem solving.[32] The challenge of applying such models to interactive art practice is that only the most tedious kinds of interactive art—and only the most tedious approaches to interactive art—can be treated as a puzzle-solving task. In more exemplary cases, the conditions are set for an inquiry whose outcome, while framed, is open-ended and designed to be generative, allowing the possibility of hypothesis formulation, rather than simply resolution. Cognitive science, with its quantitative scientific roots, has understandably shied away from such questions. But an application of embodied and situated cognition to more complex cultural contexts has potential to advance both fields.

Becoming Becoming

I noted that processual sensibilities underlay much 1960s art and we might observe the prescient but inchoate way such ideas arise first in the arts. Yet how can a felt, embodied idea be anything but inchoate, without the development of a discursive

skin? In their day, works like *Senster* and *Videoplace* could not be appreciated for want of a discursive context, so likewise it has been with "process" in general. In the years since, such a discursive skin has indeed begun to surface, in patches as it were. In *Artificial Intelligence*, Agre and David Chapman proposed deictic programming, to contest the objectivist "god's eye view" assumptions of conventional AI.[33] The situated and reactive robotics of Rodney Brooks among others were similarly inclined, as were discourses of "emergence" and iterative processes in artificial life, self-organization, and dynamical systems theory.[34] In cognitive science, enactivism, a situated and distributed cognition, challenges cognitivist attitudes.[35] In the humanities, the rise of performance theory (in some forms) contests the excesses of the linguistic turn. In science studies, actor-network-theory and Pickering's Mangle both destabilize conventional objectivist science discourses. In art theory we see the rise of relational aesthetics, and in philosophy, a resurgence of interest in Spinoza and Henri Bergson, brokered by Deleuze and later Brian Massumi, and a resurgence of pragmatism (William James, John Dewey).[36] This is quite a patchwork; some of the pieces might feel a little strained. But across diverse fields in the late twentieth century, such approaches have lurked on the margins of positivist disciplinary discourses.

Beyond a call for the recognition of the fundamentally embodied and distributed nature of cognition, the upwelling of arguments (in fields as diverse as feminism, performance studies, science studies, and cognitive and neurosciences) which contest presumed axiomatic binaries of subject/object, world/representation, suggests a fundamental and large-scale change in ontology that one might be excused for identifying as a paradigm shift.

Contemporary cognitive science, informed in part by Martin Heidegger, Edmund Husserl, and Maurice Merleau-Ponty, has brought into question not only cognitivist representationalism, but the Cartesian binaries of mind/body, self/world, subject/object, and biology/culture. The deep ontological ramifications of all this is captured with some precision by Karen Barad, who argues that the very construction of subject and object are historically contingent, and proceeds to propose a radically materialist and performative ontology, which sees "phenomena" as primary and subjects and objects contingently forming or falling out of a process of "intra-action."[37] Such an approach would be consistent with the performative ontology of Pickering, the "laying down a path in walking" of enactivism and the "ongoingness" of Alva Noë and J. Kevin O'Regan.[38] This ontological reformulation has direct relevance to the theorization of, and the creation of, interactive artifacts.

Interaction in a Developing Technological Context

The general historical picture I hope to have drawn here places the development of an aesthetics of interaction within a developing technological context. During the "heroic period" of interactive art, big questions such as "How can we deploy computational capability in artworks?" and "How can we integrate computation with material, sensorially immediate practices?" motivated work. The technological challenges of interaction, like the other technical challenges of the 1990s—problems of wireless communication, computer graphics, and of machine vision, are now effectively resolved. Culturally, the novelty of the scenario of the machine that responds to a user in real time has clearly worn off. In digital cultural practices, exploration of the modalities of interaction has been fairly thorough, though there is always room for inventive exploration of the subtle complexities of the poetics or aesthetics of interaction. In my opinion, future development of the aesthetics of interaction might usefully be framed as three areas of concern: the material artifact, the code/machine system, and the dynamics of interaction.

For two decades, the computational has been more or less "pasted on" to artifacts and social structures. And with the technology, the rhetoric of cognitivist computation has also usually been more or less uncritically pasted on. In this era of ubiquitous computation, the universe of live data, which was once called "the virtual," is increasingly anchored to physical and social context via a diversity of digital commodities. The technologies, technosocial structures, and modalities of interaction that permit this (re)union were workshopped and prototyped in "media arts" research and elsewhere over the past quarter century.

A second generation of practitioners naturalized to the digital are pursing a more organic interrelation between machine behavior, sensoriality/materiality, and conventional art practices than their forbears could, in part due to technological developments but also due to a maturation of the fine arts context. Meantime, an increasingly code- and hardware-literate community of artists is able to deploy more sophisticated aesthetic code-machines. A deepening and theoretically substantiated conception of interaction and enactive cognitive process inhering a performative ontology promises more rich and subtle systems. The conception of "interaction" has been expanded beyond user-machine, to behavior between machines, and between machine systems and the world. This leads to a kind of machinic ecology, and potential useful application of actor-network-theory.

I have proposed that across a diverse range of disciplines, we are on the cusp of a veritable Kuhnian paradigm shift toward a performative ontology. In such a Kuhnian

shift, the intractable is rendered trivial by an orthoganizing shift of perspective. In my opinion, the practice and performance of interactive art itself is an integral part of that ontological shift, and that shift offers leverage on theoretical questions that have seemed vexing under previous theoretical approaches.

Notes

1. I am here focusing my attention upon interaction design in the fine arts, on practices that extend beyond the desktop or handheld device. I am well aware of the rich complexities of the domain-specific interaction modalities in networked interactions from virtual communities (Second Life) to massively multiuser gaming (World of Warcraft) to social media from Facebook to Twitter, but these are beyond the scope of the current text.

2. This idea is explored in more depth in Simon Penny, "Desire for Virtual Space: The Technological Imaginary in 90s Media Art," in *Space and Desire. Scenographic Strategies in Theater, Art and Media*, eds. Thea Brejzek, Wolfgang Greisenegger, and Laurence Wallen (Zurich: Zurich University of the Arts, 2011), 168–185.

3. Simon Penny, "Trying to be Calm: Ubiquity, Cognitivism, and Embodiment," in *Throughout: Art and Culture Emerging with Ubiquitous Computing*, ed. Ulrik Ekman (Cambridge, MA: MIT Press, 2012), 574–605.

4. See "Senster: A Website Devoted to Edward Ihnatowicz, Cybernetic Sculptor," http://www.senster.com.

5. See "Myron Kreuger—Video Place—1989," YouTube video, 1:16, posted by "spaceduel," April 20, 2008, http://www.youtube.com/watch?v=dqZyZrN3Pl0.

6. Grey Walter's tortoises, 2:17, posted by skitterbot, August 20 2008, http://www.youtube.com/watch?v=lLULRlmXkKo.

7. Gordon Pask, "A Comment, a Case History and a Plan," in *Cybernetics, Art and Ideas*, ed. Jasia Reichardt (London: Studio Vista, 1971), 6–99.

8. A contemporary embedded microcontroller, popular in the DIY and robotic art communities, available for around 20 euros.

9. When asked if, in the late 1980s, he foresaw Internet porn, Steve Wozniak observed that the early Apples did not have enough memory to render a (color) image, to say nothing of real-time video streams. (Radio interview, December 2010, author's personal notes).

10. Moore's "law" was coined in the early 1970s by Carver Mead. It asserts that the number of transistors that can be embedded in a chip will double every two years. This implies that computer processing capability will also double at roughly the same rate.

11. This suggests a need to identify prior fields of practice that have some theoretical relevance to this realm. See Simon Penny, "Improvisation and Interaction, Canons and Rules, Emergence and

Play," in *Oxford Handbook of Critical Improvisation Studies*, eds. George Lewis and Ben Piekut (Oxford: Oxford University Press, 2012).

12. R. Buckminster Fuller, *I Seem to Be a Verb: Environment and Man's Future* (New York: Bantam Books, 1970).

13. In the spirit of Mark Johnson, I suspect our dualizing is itself a product of our bilateral symmetry. Do starfish "pentize"? See Mark Johnson, *The Body in the Mind: The Bodily Basis of Meaning, Imagination and Reason* (Chicago: University of Chicago Press, 1990).

14. See Penny, "Desire for Virtual Space," 2011.

15. Likewise, sophisticated machine vision procedures, such as "body-segmentation"—the nerdly moniker for inferring skeletal anatomy from single or multiple images—which were nontrivial and cutting-edge technical problems circa 2005, are now part of commodity devices, such as the Kinect.

16. Given the extensive evidence in developmental neurology for similar neurological adaptation, I am persuaded by this idea although as far as I am aware, it remains speculative. As we move into the generations of those "born digital" there is a call for neurophysiological research into structural and behavioral differences between those naturalized to digitality, and those who came to digital systems later in life.

17. I use the term "user" here (grudgingly) and in what follows to refer to anyone interacting with an interactive artwork. Many including myself have deplored (the instrumentality of) the term, and have sought alternatives and coined neologisms, but alternatives have been clunky and have not achieved general acceptance.

18. As "the death of the author" and reader-response theory have done in literary theory.

19. As is becoming central in some aspects of software studies. See for instance Matthew Fuller, ed., *Software Studies: A Lexicon* (Cambridge, MA: MIT Press, 2008).

20. See Simon Penny, "Twenty Years of Artificial Life," *Digital Creativity* 21, 4 (Summer 2010): 197–204.

21. A lack of clarity on such issues is typical of the tendency of technical research areas to undertheorize. See Philip E. Agre, "Toward a Critical Technical Practice: Lessons Learned in Trying to Reform AI," in *Social Science, Technical Systems, and Cooperative Work: Beyond the Great Divide*, eds. Geoffrey C. Bowker, Susan Leigh Star, Les Gasser, and William Turner (Mahwah, NJ: Lawrence Erlbaum Associates, 1997), 131–157. A more subtle point is that to the extent that such modalities are intuitive in this sense, neurological impact will be minimal. But as digital behaviors themselves become "naturalized" at the level of culture and of embodied cognition, we will see a drift in what is taken to be "intuitive."

22. This kind of extension of the sensory and motor homunculi has been famously explored by Merleau-Ponty, Gregory Bateson, and more recently Lambros Malafouris around the example of the Blind Man's Stick. See Maurice Merleau-Ponty, *Phenomenology of Perception* (London: Routledge and Kegan Paul, 1965); Gregory Bateson, *Steps to an Ecology of Mind*, (Chicago: University of

Chicago Press, 2000); and Lambros Malafouris, "Beads for a Plastic Mind: The 'Blind Man's Stick.' (BMS) Hypothesis and the Active Nature of Material Culture," *Cambridge Archaeological Journal* 18, 3 (2008): 401–414.

23. This phrase is the title of chapter 11 of *The Embodied Mind: Cognitive Science and Human Experience*, by Francisco J. Varela, Evan Thompson, and Eleanor Rosch (Cambridge, MA: MIT Press, 1992). From the author's note (241): "Our guiding metaphor is that a path exists only in walking." The term has been taken up in aspects of contemporary cognitive science and philosophy of mind, notably in the work of Alva Noë and Kevin O'Regan. See J. Kevin O'Regan and Alva Noë, "A Sensorimotor Account of Aision and Consciousness," *Behavioral and Brain Sciences* 24 (2001): 939–1031.

24. Much of the thinking behind academic and industrial machine vision research still labors under the naïve conception that frames are a fundamental aspect of reality (rather than a skeuomorphic convention) and likewise that "lines" in images can be unproblematically associated with objects or edges in a physical space. Computer science libraries and journals are replete with papers on topics like "edge detection," in some cases the authors seem unaware that a video image depends on optics developed in film cameras, themselves designed to implement the graphical perspective, a conventionalized geometrical system for representing spatial depth on a plane.

25. See Nathaniel Stern, "The Implicit Body as Performance: Analyzing Interactive Art," *Leonardo* 44, 3 (June 2011): 233–238.

26. See Agre, "Toward a Critical Technical Practice," and Andrew Pickering, *The Mangle of Practice: Time, Agency, and Science* (Chicago: University of Chicago Press, 1995).

27. One might add Evan Thompson, Ezequiel Di Paolo, Bruno Latour, Karen Barad, and others. See Evan Thompson, *Mind in Life: Biology, Phenomenology, and the Sciences of Mind* (Cambridge, MA: Harvard University Press: 2007); Ezequiel Di Paolo and Hanne De Jaegher, "Participatory Sense-Making: An Enactive Approach to Social Cognition," *Phenomenology and the Cognitive Sciences* 6, 4 (2007): 485–507; Bruno Latour, *Reassembling the Social: An Introduction to Actor-Network-Theory* (Oxford: Oxford University Press, 2007); and Karen Barad, *Meeting the Universe Halfway: Quantum Physics and the Entanglement of Matter and Meaning* (Durham, NC: Duke University Press Books, 2007).

28. For examples of such work, see Simon Penny, "Towards a Performative Aesthetics of Interactivity," *The Fibreculture Journal* (November, 2011), http://nineteen.fibreculturejournal.org/fcj-132-towards-a-performative-aesthetics-of-interactivity.

29. Pickering, *The Mangle of Practice*, 1995.

30. See Edwin Hutchins, "Imagining the Cognitive Life of Things," in *The Cognitive Life of Things: Recasting Boundaries of the Mind*, eds. Lambros Malafouris and Colin Renfrew (Cambridge, UK: McDonald Institute for Archaeological Research, 2010), 91–101; and David Kirsh and Paul Maglio, "On Distinguishing Epistemic from Pragmatic Actions," *Cognitive Science* 18 (1995): 513–549.

31. Kirsh and Maglio, "On Distinguishing Epistemic from Pragmatic Actions."

32. Ibid.

33. Philip E. Agre and David Chapman, "Pengi: An Implementation of a Theory of Activity," *Proc., AAAI-87* (Seattle, WA: 1987), 268–272.

34. See Rodney Brooks, "Intelligence Without Reason," Massachusetts Institute of Technology. Artificial Intelligence Laboratory. A.I. Memo no. 1293, April 1991; "A Robust Layered Control System for a Mobile Robot," Massachusetts Institute of Technology. Artificial Intelligence Laboratory. A.I. Memo no. 864. September 1985; and "Elephants Don't Play Chess," *Robotics and Autonomous Systems* 6 (1990): 3–15. See also J.A. Scott Kelso, *Dynamic Patterns: The Self-Organization of Brain and Behavior* (Cambridge, MA: MIT Press, 1995).

35. Enactivism, situated cognition, and distributed cognition are three major variants of postcognitivist cognitive science.

37. See Barad, *Meeting the Universe*, 2007.

38. See O'Regan and Noë, "A Sensorimotor Account," 2001.